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IMPROVED NUMERICAL METHODS FOR TURBULENT VISCOUS RECIRCULATING FLOWS*

A PROGRESS REPORT

A. Turan
Avco Everett Research Laboratory, Inc.

The hybrid-upwind finite difference schemes employed in generally available combustor codes possess excessive numerical diffusion errors which preclude accurate quantitative calculations. The present study has as its primary objective, the identification and assessment of improved solution algorithm as well as discretization schemes applicable to analysis of turbulent viscous recirculating flows. The assessment is to be carried primarily in two dimensional/axisymetric geometries with a view to identifying an appropriate technique to be incorporated in a three-dimensional code.

To accomplish the above objective, a semi-exhaustive survey was carried out of the relevant literature for computing turbulent viscous recirculating (incompressible) flows. The following techniques were identified as candidates offering the best compromise between accuracy and boundedness and hence were selected for further evaluation (quantitatively) in two-dimensional problems.

a) Second Order Upwind Differencing

b) Modified Skew Upwind Differencing

c) Operator Compact Implicit Differencing

d) Various Advanced Solvers

Item d encompasses a myriad of solvers including the strongly implicit scheme (SIP) and incomplete Cholesky (IC) as base solvers, accelerated by a variety of techniques. These accelerators include conjugate gradient (CG), multi-grid (MG) and block correction (BC) algorithms.

Second order upwind differencing yielded minor oscillations when applied to the test problem for the convection-diffusion of a scalar for various inlet angles. The same behavior was also observed in the driven cavity problem for some of the high Reynolds number cases considered.

Bounded skew upwind differencing including streamwise source corrections (necessitated by the poor performance of the original skew scheme in the driven cavity problem) is currently being evaluated for select test problems. To overcome the arbitrariness and limitations introduced by the particular bounding scheme, work on a further alternative including a novel, mass-based formulation incorporating an optimized interpolator is in progress. This has been shown to provide more

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accurate and bounded predictions than previous applications of skew upwind differencing.

Operator compact implicit differencing with a formal accuracy of fourth order in smooth flow regions, has been formulated in a finite difference framework and select examples will be discussed that highlight accuracy and boundness issues. Work is also in progress to reformulate the scheme in a conservative, flux-based finite volume manner incorporating boundness at the expense of accuracy in high Peclet number regions of the flow.

In incompressible flow predictions utilizing the segregated SIMPLE derivative algorithms, most of the effort goes to satisfying the incompressibility constraint, i.e., the pressure/correction equation. The advanced solvers considered for this effort are designed to provide faster convergence rates for this "Poisson-like" equation as well as being inherently more suited for solving extended node cluster formulations arising either due to the particular differencing scheme and/or the increase in the dimensionality of the problem. Studies aimed at assessing the performance of these solvers for the linearized pressure/correction equation in various test problems have identified a group of optimum base solvers and accelerators. These include SIP-MG, SIP-BC and IC-MG. Issues related to non-linear applications including 3-D problems will be discussed.

Select results from all phases of the work (where available) will be presented and the relevant issues will be discussed in detail.